Investigating the Role of Poultry in Livelihoods and the Impact of HPAI on Livelihoods Outcomes in Africa: Evidence from Ethiopia, Ghana, Kenya and Nigeria

By

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Investigating the Role of Poultry in Livelihoods and the Impact of HPAI on Livelihoods Outcomes in Africa:

Evidence from Ethiopia, Ghana, Kenya and Nigeria

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Abstract

In this paper we investigate the role of poultry in the livelihoods portfolios of households and the impact of supply and demand shocks that may be caused by Highly Pathogenic Avian Influenza (HPAI) on various livelihoods outcomes of households in four Sub-Saharan African (SSA) countries. The study countries include Ethiopia and Kenya in East Africa and Ghana and Nigeria in West Africa. These countries represent a spectrum of SSA countries in terms of disease status, role of poultry sector and means of disease spread. By using nationally representative household level secondary data and discrete choice methods (probit model and zero inflated negative binomial model) we profile the household, farm and regional characteristics of those households who are most likely to keep poultry, and those who are most likely to be engaged in intensive poultry production, i.e., keep larger household flocks. We estimate the impact of the disease outbreaks and scares/threats on livelihood outcomes by using matching methods (i.e., propensity score matching). The results of this study generate valuable information regarding the role of poultry in the livelihoods of small-scale poultry producing households and the livelihood impacts of HPAI induced demand and supply shocks. Such information is critical for the design of targeted and hence efficient and effective HPAI control and mitigation policies.

Keywords: Highly Pathogenic Avian Influenza (HPAI), demand shock, supply shock, livelihoods, probit model, zero inflated negative binomial model, propensity score matching

1. Introduction

Poverty is both a cause and a consequence of inability to cope with shocks. The poor are often considered more vulnerable to shocks because of the assumed lack of diversification in their income and/or asset portfolio. In low income countries of Sub-Saharan Africa (SSA) this vulnerability of the poor to various shocks is considered to be of utmost importance for policy targeting. In the limited livelihoods diversification that poor households tend to have, livestock constitutes an important source of income and in general comprises the most important asset. The potential livelihoods impacts of a shock that affects the livestock sector, particularly the type of livestock kept by the poorest and most vulnerable, such as poultry, is therefore of paramount importance to policy makers.

In this paper we assess the livelihoods impacts of a shock to the poultry sector in the form of a disease, namely Highly Pathogenic Avian Influenza (HPAI), in four different countries in SSA. The study countries include Ethiopia and Kenya in East Africa and Ghana and Nigeria in West Africa. HPAI virus has been circulating in SSA since February 2006, when the first case was confirmed in Kaduna state, Nigeria. This virus has directly or indirectly affected the poultry sectors and overall economies of various countries in SSA. Benin, Burkina Faso, Cameroon, Djibouti, Ghana, Ivory Coast, Niger, Nigeria, Sudan, Togo and Zimbabwe are among the countries affected directly through single or multiple outbreaks. SSA countries that were indirectly affected include countries such as Ethiopia, Kenya and South Africa, whose poultry sectors suffered from scares, for example false alarms as a result of mass poultry loss to other diseases, and/or from HPAI threats, due to outbreaks in neighbouring countries.

With fears of a human pandemic, substantial funding has been channeled to prevent an avian flu outbreak and/or to control it in the event of an outbreak. In the 2006 meetings in Beijing, multilateral donors and developed countries pledged US$1.9 billion towards HPAI prevention and control programmes (World Bank, 2006). This figure far exceeded the initial target, highlighting the perceived importance of this issue. Strengthening of the disease surveillance and control systems in developing countries was a significant component of this fund. Another significant part of the fund was earmarked for controlling the spread of the disease, especially through the preservation of livelihoods so as to improve reporting of the outbreak by the poor. In the specific context of HPAI outbreaks (and also other animal diseases), disease control and livelihoods preservation are inextricably linked. The incentive to report an outbreak, and thus facilitate the implementation of control measures, is a function of the effect of HPAI on livelihoods.

This link rationalizes the system of compensation for the loss of poultry from control measures, i.e. in economic terms a supply shock. In this paper we bring forth the elements of the HPAI shock that are more nuanced than the usual way policy has dealt with them, which included focusing solely on the supply shock effects. We emphasize that in economic terms it is extremely important to treat an HPAI outbreak as both a demand shock (i.e., reduction in demand due to consumer panic and associated fall in the price/value of poultry and eggs) and a supply shock (i.e., reduction in bird supply as a result of bird mortality from disease or from control measures). The former is generally non-localized and, more importantly, can occur even in the absence of an outbreak since it is a perception based consumer response. The demand shock is also often discrete, and evidence from several countries suggests that the impact of a demand shock far outweighs that of a supply shock caused by disease mortality or mortality from control measures such as culling.

Characterisation of the shocks as supply and demand shocks, compounded with the fact that HPAI spread is essentially transboundary, provides us with the first set of rationale for looking at the set of four SSA countries as a group. The two study countries in East Africa, namely Ethiopia and Kenya, have not yet experienced any outbreaks, however, they share a physical border with each other and with Sudan, where several HPAI outbreaks have occurred, thereby implying informal trade effects. The two study countries in West Africa, namely Ghana and Nigeria, have both experienced outbreaks and are effectively neighbors from a disease spread standpoint being on the same bird flyways. Though science of the channels of spread (trade and/or flyways) is still not definitive, either or both of the two channels are considered important in the spread of the disease.

Regarding the first channel, i.e. the trade linkage between Kenya and Ethiopia, the current levels of trade (most of which is informal and/or undocumented) is often taken as a basis for downplaying the interdependence in disease transmission. This reasoning, we argue, is based on ignoring a very important dynamic, i.e. the endogenous initiation or expansion of trade following an outbreak. If Ethiopia has an outbreak and Kenya has not and if livelihoods in Ethiopia are affected significantly, trading of birds out of Ethiopia will be a rational response, at least in the short run. Similarly, if both Kenya and Ethiopia have an outbreak or are affected through a demand link channel, arbitrage will materialize with the transfer of birds towards high compensation areas through informal trading.

The study countries represent a spectrum regarding HPAI status and the importance of poultry in small-scale producers' livelihoods outcomes. In Nigeria, HPAI is considered endemic; Ghana has experienced three outbreaks, and in Kenya and Ethiopia, where HPAI outbreaks have not yet occurred, scares and threats of this disease have significantly affected the poultry sectors. The countries also vary in terms of various factors, including the size and structure of the poultry sector; reliance of the poor on poultry, and the levels of diversification in income sources and in assets that determine the capacity to cope with shocks.

The results of our analyses show some interesting and important results from a policy perspective. Our reliance on nationally representative data provides an *ex post* vindication by revealing the significant inter-regional disparities in household's income and asset portfolio. Most localized studies looking at the effect of these shocks are case study based (i.e., on one area or region of the study country) and can therefore not be treated as generalisable. Further, the datasets that we use allow us to look at the whole income and asset portfolio, thereby providing a more accurate measure of the impact of the disease. If for example one looked only at the impact of HPAI on the income from poultry without accounting for its role in the whole income stream, the effects can be grossly inaccurate and can even be exaggerated.

Contrary to our *ex ante* conjecture, we find that surprisingly poor households are significantly diversified in the four study countries, though the regional differences are significant. When livelihoods portfolios are diversified, any idiosyncratic shock would have only limited effect particularly if the contribution of the livelihoods activity that is affected by the shock to the income and asset portfolio is small. This turns out to be true in case of poultry for most regions in the study countries. Once again the regional differences in impacts need attention. More importantly, our results highlight the importance of the nature of the shock. An idiosyncratic shock to a sector (such as poultry) implies negligible co-variance with other sectors (such as other livestock or crop production). Hence, ignoring the shocks to upstream and downstream linkages, the draw upon the other sectors in the portfolio could be overestimated.

Yet, in the short to medium run the evidence from the SSA countries show that a shock to an important livestock activity undertaken by the poor will not have a significant effect, on average. This is an important result but does not imply that earmarking of funds for preserving livelihoods is not important in the context of African countries. As long as poor are loss averse and effects on livelihoods is non-zero, there exists a significant potential for small effects on livelihoods to translate into first order effects on disease control.

The importance of our findings lies in understanding the following points. We find that the livelihood strategies of the poor in SSA are characterized by significant diversification but their ability to cope with risks is contingent on the nature of shock (idiosyncratic versus generalized). Further, in all countries there are significant regional differences with livelihood hotspots for poultry. A balance sheet perspective on households will likely identify hotspots for other sectors in each country. Policies need to target these areas, though our demand shock perspective makes all areas vulnerable to a disease outbreak or threat. The importance of information management (in regional, national or even international context) can therefore not be overstated. Finally, our findings point at the importance of livelihoods diversification as a policy in itself. Much of the diversification observed in the four study countries has been fostered by the households themselves and there are significant gains to be made from enhancing portfolio diversification. This is exemplified by limited non-farm sector in many regions of the study countries, where government policies and institutions have a disproportionately larger role to play.

In the context of the literature this paper contributes in different ways. There has been an increasing number of studies which investigated the economy-wide, inter-sectoral or sector-wide impacts of HPAI in several SSA countries (e.g., You and Diao, 2007; Diao, 2009; Diao et al., 2009; Schmitz and Roy, 2009; Thomas et al., 2009; Thurlow, 2009). Some of these studies are linked with household data through micro-simulation routines to assess the impact at the household level.

Important as these effects are, they do not assess effects at the household level or do so in a summary (for example households clubbed into decile groups). Most importantly, these studies cannot differentiate across households based fully on their income and asset portfolio. The number of studies which investigated the impact of HPAI on small-scale, household level producers' livelihoods has however been scant (e.g., Bush, 2006; Kimani et al., 2006; UNDP 2006; Obayelu, 2007; UNICEF/AED, 2008). These studies were mainly based on qualitative and/or quantitative data generated through rapid assessment techniques conducted as case studies in selected states or regions of the study countries. We argue that the area/region specific case studies and qualitative methods both have significant limitations when producing estimates of the impact of the shock on livelihoods. These location specific case studies can present a very biased picture and do not generate policy prescriptions for resource allocation, a very important requirement in developing economies under strict budget constraints. The same critique applies to qualitative methods.

Starting from the prior that poultry plays a considerable role in household level producers' various livelihoods outcomes, such as cash income, wealth, food and nutrition security, and insurance against shocks, to name a few (see e.g., Kushi et al. 1998; Kitalyi 1998; Tadelle and Ogle 2001; Tadelle et al. 2003; Njenga 2005; Houndonougbo 2005; Aboe et al., 2006; Blackie, 2006; Aklilu et al., 2008; Chinombo et al., 2008) we see a merit in conducting a detailed investigation of the impact of HPAI on small-scale, household level poultry producers' livelihoods by using rigorous quantitative methods. The evidence from all four study countries clearly shows that a great majority of the poultry populations of these countries are managed by household level producers, with minimal or no biosecurity measures (see e.g., Alemu et al., 2008; Aning et al., 2008; Obi et al., 2008; Omiti and Okuthe, 2008).

Information regarding the role of poultry in the livelihoods of small-scale poultry producing households and the livelihood impacts of HPAI induced demand and supply shocks is critical for the design of targeted and hence efficient and effective control and mitigation policies. In this paper we aim to fill this gap by using nationally representative household level data from the study countries to answer the following questions:

(i) Who are the poultry keepers? Are they poor? Do they have diversified income and/or asset portfolios? Within a country where are they located, i.e. are there significant regional differences?

(ii) Among the poultry keepers what is the intensity of participation in poultry production? Who are the farmers who participate in poultry with greater intensity? In quantitative terms we examine these by assessing the flock sizes of the poultry keepers.

(iii) Together (i) and (ii) imply that we can hypothesize the characteristics and location of poultry producers in the study countries who are likely to bear the brunt of the disease.

(iv) What is the effect of the disease outbreaks and scares/threats on livelihood outcomes? How can we assess this effect in the absence of actual data on affected households?

Answers to these research questions are expected to assist in the design of efficient, effective, and equitable interventions for mitigation and control of HPAI in the study countries, with possible implications for similar countries in the rest of SSA.

The rest of the paper is organized as follows. The next section provides background information regarding the HPAI status in each study country and summarises the documented evidence on poultry demand and supply shocks caused by HPAI outbreaks and scares in these countries. Section 3 explains the econometric models used to tackle the research questions. Section 4 introduces the data sources and presents descriptive statistics. Section 5 reports the results of the analysis and the final section concludes the paper with implications for HPAI prevention and control policies.

2. Background: HPAI status and economic impacts

In this paper we study two West African countries, namely Nigeria and Ghana, which have experienced multiple HPAI outbreaks. In Nigeria, there have been several HPAI outbreaks since February 2006, affecting 27 out of 36 states, the most recent outbreak occurred in July 2008 (Obi et al., 2008). According to the records of the World Bank-funded Avian Influenza Control Program, between February 2007 and January 2008, N623,077,880 (US$4,215,683) has been paid to compensate farmers whose birds were culled. No information is available on the costs of culling, diagnostic testing of samples, cleaning and disinfection, and other administrative costs (Obi et al. 2008). Regarding the impacts of HPAI on the poultry sector, a study conducted by the UNDP in 2006, right after the initial outbreaks, revealed that the official confirmation of HPAI in Nigeria caused initial panic, resulting in the total boycott of poultry and poultry products. Consequently, within two weeks, egg and chicken sales declined by 80.5%, due to demand shock, and up to four months after, prices had not recovered up to 50% pre-HPAI levels. The study found that although the highest bird mortality rates occurred in commercial farms, overall small-scale, household level poultry producers, especially those in rural areas, as well as medium scale farmers were most severely affected by the HPAI outbreaks, since these smaller scale producers lack necessary assets for recovery and often do not qualify for compensation (especially village extensive, small-scale poultry producing households). Affected backyard producers suffered up to a 100% income loss, while non-affected producers also witnessed income losses as high as 68.2% (UNDP, 2006; Obi et al., 2008).

State level studies conducted in Nigeria found that HPAI resulted in a 57% drop in the chicken prices in the Kwara state (Obayelu, 2007). The household level demand shock was as high as 80%, and supply shock resulted in 75% of poultry farmers to stop ordering of new supplies of birds and to opt out of poultry farming altogether. According to Obayelu (2007) small scale commercial producers and backyard poultry farmers suffered the most income losses as a result of HPAI. A more recent study conducted by UNICEF and AED in Kano and Lagos states found that HPAI shocks resulted in substantial losses in employment in the poultry sector, as well as sharp decreases in prices of poultry. In Kano, the price of chicken in the markets dropped by as much as 90%, while in Lagos the price fell by 81.25% (UNICEF/AED, 2008).

Anecdotal evidence from Ghana suggests that during the 2006 outbreaks in the neighboring countries, the magnitudes of supply and demand shocks were large. In terms of supply shocks, poultry producers could not sell their produce and due to the increasing costs of keeping poultry (e.g., feeding and maintaining costs) they had to dispose of their produce as quickly as possible and hence they sold at extremely low prices. For example a crate of eggs was sold at 63.3% of its normal price (Aning et al., 2008). In terms of demand shocks, Ministry of Food and Agriculture of Ghana reported that "the scare of the bird flu alone led to a drastic reduction in the demand for poultry and poultry products." It was recorded by the Ghana National Association of Poultry Farmers that poultry consumers reduced their demand by 40% during these HPAI scares (GNAPF, 2006).

There have been three actual outbreaks of HPAI in Ghana in 2007 (Aning et al., 2008). There is no published information available on the demand and supply shocks and changes in prices after the outbreaks. There is, however, anecdotal information on the numbers of farmers who have gone bankrupt due to the loss of markets as a result of the ban on poultry and the reductions in the demand for poultry products, during and sometime after the outbreaks. For example, according to the Poultry Farmers' Association, the total number of their broiler producing members was reduced by 95%, whereas their broiler chickens was reduced by 83%. The number of their egg producing members also fell, though at a lower rate of 30%. At the country level, however, the total number of egg producers plummeted by 66.7%. These figures provide some indicators of the supply and demand shocks suffered by poultry farmers in Ghana (Aning et al., 2008).

In this paper we also study two eastern African countries, namely Kenya and Ethiopia, which have not had actual HPAI outbreaks to date. These two countries however have experienced HPAI scares and threats, which affect the poultry sector and the household level livelihoods through the demand shocks they cause. Both of these countries are highly susceptible to the introduction of HPAI. Kenya is located along a migratory route of wild birds, whereas both of these countries, and especially Ethiopia, share a border with neighbouring Sudan, where the virus is present and illegal trade activities across the borders are paramount (Alemu et al., 2008; Omiti and Okuthe, 2008). Given the susceptibility of these two countries to HPAI, we wanted to understand *ex ante* livelihoods impact of a possible HPAI outbreaks and the role of poultry in the households' livelihoods.

In Kenya there was a major HPAI scare that took place September 2005 through March 2006 (Omiti and Okuthe, 2008), which was initiated by misguided reports by the media, compounded by HPAI actual outbreaks in neighbouring Sudan. Kimani et al. (2006) assessed the demand and supply shocks caused by this scare to be highly significant. According to this study, as a result of this scare, 25% of farmers prematurely culled their birds and all farmers interviewed reduced their flock sizes between 2 to 39 percent due to various reasons related to the scare (e.g., premature selling, postponement or cancellation of day-old-chicks, and unavailability of new chicks as hatcheries reduced production). The prices of poultry and poultry products were also affected by the HPAI scare. The price of broiler chicken fell by 15% per kg, and the prices of eggs fell by 15.3% per tray. The demand and supply shocks caused by the scare also reduced the prices of indigenous eggs and chickens, by 7.2% per tray and 26.5% per kg, respectively (Kimani et al., 2006). The overall financial losses associated with the HPAI scare are estimated to be Ksh2.3 billion (US$30.7 million) (Omiti and Okuthe, 2008).

Finally, in Ethiopia there was an HPAI scare in 2006, due to a false alarm in a state run poultry multiplication centre. This scare caused a massive demand shock, which subsequently led to sharp falls in poultry prices (Alemu et al., 2008). Bush (2006) reports that this scare led to a demand shock, especially in urban areas, which decreased poultry demand by 25-30 %. As a result of reduction in urban demand and the consequent over-supply of local markets, the prices of chicken sold at the local markets dropped by 50-60%. The scare, however did not affect egg supply, demand and price (Bush, 2006).

3. Methodology

As stated in the introduction, in order to understand the impact of HPAI on livelihoods, we first profile the characteristics of the households who choose poultry production as a livelihoods activity; and among those, we profile the characteristics of those households who are engaged in more intensive poultry production. To investigate these issues we estimate probit and zero inflated count data models, respectively. Following these, we measure the livelihoods impacts of the HPAI supply and demand shocks on households who are engaged in poultry and who are engaged in intensive poultry. For the latter analysis we use the propensity score matching approach. Information on the poultry keeping and intensive poultry keeping households' profiles, as well as the information on the livelihoods impacts these households may suffer, are expected to aid in the design of targeted interventions. The econometric models used in this paper are explained into greater detail below.

3.1. Determinants of participation in poultry production

Household level participation in poultry as a livelihoods activity is modelled following the random utility framework proposed by McFadden (1974). A non-separable farm household model is assumed given that a great majority of small-scale poultry producers in the study countries are non- or semi-commercial producers who mainly produce for own household consumption (see Singh *et al.*, 1986; de Janvry *et al.* 1991). A reduced form of the model for a poultry producer with missing markets for poultry products describes the overall welfare of the household to be a function of the household (H) and farm level (F) characteristics as well as regional factors (R), such as market integration and density of poultry. That is:

$$U = U(\Omega_H, \Omega_F, \Omega_R) \quad (1)$$

let $U_i^*(\Omega)$ denote the maximum utility level the household i can achieve given its constraints, if the household participates in poultry activity . Let $U_{-i}^*(\Omega)$ denote maximum constrained utility otherwise. Both of these utility levels assume optimal choices of production and consumption.

In the random utility model, the utility the household derives from undertaking poultry activity consists of two parts, an observable part and an unobservable one (McFadden, 1974). The utility levels the household derives from participating in poultry production and otherwise respectively:

$$U_i^*(\Omega) = \overline{U}_i^*(\Omega) + \varepsilon_i$$

and

$$U_{-i}^*(\Omega) = \overline{U}_{-i}^*(\Omega) + \varepsilon_{-i} \quad (2)$$

The household chooses to participate in poultry production if and only if the utility the household derives from participating in the poultry activity is higher than that of not participating in it. That is,

$$\overline{U}_i^*(\Omega) + \varepsilon_i \succ \overline{U}_{-i}^*(\Omega) + \varepsilon_{-i}$$

or

$$\overline{U}_i^*(\Omega) - \overline{U}_{-i}^*(\Omega) \succ \varepsilon_{-i} - \varepsilon_i \quad (3)$$

The level of utility derived from poultry activity is not observable, however the household's actual choice is. For the dichotomous choice case the household's choice to participate in poultry production can be characterized by a variable I_i, such that

$$I_i = \begin{cases} 1 & \text{if } U_i^*(\Omega) \succ U_{-i}^*(\Omega) \\ 0 & \text{if } U_i^*(\Omega) \le U_{-i}^*(\Omega) \end{cases} \quad (4)$$

The household takes a decision on whether or not to participate in poultry production. The solution to this participation decisions yields of the household's optimal participation choice I^*, where the probability of observing a household's participation in poultry activity is given by

$$\Pr(i) = \Pr(I_i^* = 1) = \Pr(U_i^*(\Omega) \succ U_{-i}^*(\Omega)) = M(\overline{U}_i^*(\Omega) - \overline{U}_{-i}^*(\Omega) \succ \varepsilon_{-i} - \varepsilon_i) \quad (5)$$

where it is commonly assumed that both error terms are normally distributed with mean zero and constant variance, and where M is their cumulative distribution function that is assumed to have a standard normal distribution. In this study, therefore, whether or not a household decides to participate in poultry production implicate a dichotomous, binary choice. Equation (5) can be estimated with a univariate Probit model for a binary outcome of taking part in this livelihoods activity.

3.2. Determinants of poultry flock size

The Poisson model for count data is used to model the household's decision regarding the number of birds to keep (Greene, 1997). The probability of raising *k* number of poultry given *n* independent possibilities is represented by the binomial distribution

$$P(Y=k)=\binom{n}{k}p^{k}(1-p)^{n-k} \tag{6}$$

where $\binom{n}{k}=\frac{n!}{k!(n-k)!}$ and p is the probability of keeping k number of poultry k .

Statistical theory states that a repetition of a series of binomial choices, from the random utility formulation, asymptotically converges to a Poisson distribution as n becomes large and p becomes small.

$$\lim_{n\to\infty}\binom{n}{k}p^{k}(1-p)^{n-k}=\frac{e^{-\lambda}\mu^{k}}{k!} \tag{7}$$

where $p=\mu/n$ and μ is the mean of distribution, such as the mean number of poultry kept per household. This formulation allows modelling of the probability that a household chooses to raise a number of poultry k given a parameter μ (the sample mean).

Each household makes a series of discrete choice decisions on whether or not to raise poultry on the farm, resulting in the number of poultry kept. Accordingly, Poisson specification is used to model the increase in household utility from an additional bird raised. The Poisson regression model is the development of the Poisson distribution presented in equation (7) to a non-linear regression model of the effect of independent variables x_i on a scalar dependent variable y_i. The density function for the Poisson regression is

$$f(y_i/x_i)=\frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!} \tag{8}$$

where the mean parameter is the function of the regressors x and a parameter vector β is given by

$$E(y_i/x_i)=\mu_i=\exp(x_i'\beta) \qquad and \qquad y=0,1,2,..... \tag{9}$$

where

$$\exp(x_i'\beta)=\exp(\beta_0)+\exp(\beta_1 x_{1i})+\exp(\beta_2 x_{2i})....+\exp(\beta_k x_{ki}) \tag{10}$$

Also note that

$$\beta_j=\frac{\partial E[y_i/x_i]/\partial x_{ji}}{E[y_i/x_i]}=\frac{\partial \log E[y_i/x_i]}{\partial x_{ji}} \tag{11}$$

That is the coefficients of the marginal effects of the Poisson model can be interpreted as the proportionate change in the conditional mean if the j^{th} regressor changes by one unit. Finally the Poisson model sets the variance to equal to the mean. That is

$$V(y_i / x_i) = \mu_i(x_i, \beta) = \exp(x_i^{'}\beta) \qquad (12)$$

This restriction of the equality of the mean and variance in the Poisson distribution is often not realistic as it has been found that the conditional variance tends to exceed the mean resulting in over-dispersion problem (Cameron and Trivedi, 1986; Grogger and Carson, 1991; Winkelmann, 2000). If over-dispersion problem exists, the conditional mean estimated with a Poisson model is still consistent though the standard errors of β are biased downwards (Grogger and Carson, 1991). A more generalized model to account for the over-dispersion problem is based on the negative binomial probability distribution expressed as

$$f(y_i / \mu, \alpha) = \frac{\Gamma(y + \alpha^{-1})}{\Gamma(y+1)\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu} \right)^{\alpha^{-1}} \left(\frac{\mu}{\alpha^{-1} + \mu} \right)^{y} \qquad (13)$$

where

$$\mu_i = \exp(x_i^{'}\beta) \qquad y = 0,1,2.... \qquad (14)$$

and $\alpha \geq 0$ characterises the degree of over-dispersion, or the degree to which the variance differs from the mean.

Cameron and Trivedi (1990) have proposed a regression-based test for over dispersion, which tests for the significance of the α parameter as compared to the Poisson model (Greene, 1998). The test is based on the hypothesis that the Poisson model, $(y - E[y])^2 - E[y]$ has mean zero and that under both the null and the alternative hypotheses the Poisson model gives consistent estimates of $E[y_i] = \mu_i$. The test is based on the hypotheses

$$H_0 : Var[y_i] = \mu_i$$

vs.

$$H_1 : Var[y_i] = \mu_i + \alpha g(\mu_i) \qquad (15)$$

In this study, the test of equality of the mean and variance fails to hold, for all of the study countries. Therefore Negative Binomial Model is considered. However, in each study country there are many zero observations for households who did not keep poultry in the survey year in which the data were collected. Consequently the Zero-inflated Negative Binomial (ZINB) model was estimated to account for both the over-dispersion and the excess zeros (Long, 1997; Greene, 1998).

In ZINB, for each observation, there are two possible data generation processes; the result of a Bernoulli trial determines which process is used. For observation *i*, Process 1 is chosen with probability φ_i and Process 2 with probability $1 - \varphi_i$. Process 1 generates only zero counts, whereas Process 2, $g(y_i|\mathbf{x}_i)$ generates counts from a negative binomial model:

$$y_i \sim \begin{cases} 0 & \text{with probability } \varphi_i \\ g(y_i|\mathbf{x}_i) & \text{with probability } 1 - \varphi_i \end{cases} \qquad (16)$$

The probability of $\{Y_i = y_i|\mathbf{x}_i\}$ is

$$P(Y_i = y_i|\mathbf{x}_i, \mathbf{z}_i) = \begin{cases} \varphi(\gamma^{'}\mathbf{z}_i) + \{1 - \varphi(\gamma^{'}\mathbf{z}_i)\}g(0|\mathbf{x}_i) & \text{if } y_i = 0 \\ \{1 - \varphi(\gamma^{'}\mathbf{z}_i)\}g(y_i|\mathbf{x}_i) & \text{if } y_i > 0 \end{cases} \qquad (17)$$

When the probability φ_i depends on the characteristics of observation *i*, φ_i is written as a function of $\mathbf{z}_i'\gamma$, where $\mathbf{z}_i$ is the vector of zero-inflated covariates and γ is the vector of zero-inflated coefficients to be estimated. The function F that relates the product $\mathbf{z}_i'\gamma$ (which is a scalar) to the probability φ_i is called the zero-inflated link function, and it can be specified as either the logistic function or the standard normal cumulative distribution function (the probit function) (Greene, 1998).

The mean and variance of the zero-inflated negative binomial model (ZINB) are:

$$E(y_i|\mathbf{x}_i, \mathbf{z}_i) = \mu_i(1-\varphi_i)$$
$$V(y_i|\mathbf{x}_i, \mathbf{z}_i) = \mu_i(1-\varphi_i)(1+\mu_i(\varphi_i+\alpha)) \quad (18)$$

To test whether ZINB model fits better than Negative Binomial to the data for each study country we performed Vuong test. This test is for nested models and is used to determine which zero-inflated model explains the data better (Vuong, 1989). The test favors the ZINB model for all countries, suggesting that there is a separate process for households' decision to keep poultry and the number they decide to keep.

3.3. Estimating livelihoods impact of HPAI by using the propensity score matching method

Since we do not have nationally representative data on the same households from before and after the HPAI outbreaks and scares we use an *ex ante* evaluation method as proposed by Chimera & Taber (2000) and Todd & Wolpin (2005). The main feature of this approach is the fact that all the factual outcomes are about non-treated individuals, that is, none of them has yet been exposed to the policy (in this case, HPAI outbreak or shock) that the analyst is to evaluate. The matching procedure is between an individual *i* who we observe (or estimate) the outcome as non-treated, and an individual *j* that mimics the outcome individual *i* would have under the new policy/shock. Then it must be $Y_i^1 = Y_j^0$, i.e.: the factual outcome for individual *j* under the status quo policy regime must be equal the one of individual *i* under the new policy/shock (hereafter referred to as the treatment).

The estimation of an average treatment effect in observational studies can produce biased results when we use a non-experimental estimator. The typical problem in this type of studies is that the assignment of subjects to the treatment and control groups is not random and therefore the estimation of the average treatment effect is usually biased as a result of the existence of confounding factors. For that reason, the matching between treated and control subjects becomes difficult when there is an *n*-dimensional vector of characteristics. The matching approach is one possible solution to the selection problem and has become a popular approach to estimate causal treatment effects (Caliendo and Kopeinig, 2005). Its basic idea is to find in a large group of non-treated individuals or households who are similar to the participants in all relevant pre-treatment characteristics X. That being done, differences in outcomes of this well selected and thus adequate control group and of treated group can be attributed to the treatment.

Since conditioning on all relevant covariates is limited in case of a high dimensional vector *X* ('curse of dimensionality'), Rosenbaum and Rubin (1983) suggest the use of so-called balancing scores $b(X)$, i.e. functions of the relevant observed co-variants X such that the conditional distribution of X given $b(X)$ is independent of assignment into treatment. This is the conditional independence assumption (CIA). One possible balancing score is the propensity score, i.e. the probability of participating in a treatment given observed characteristics X. The matching procedures based on this balancing score are known as propensity score matching (PSM).

Besides CIA, a second assumption of matching requires that treatment observations have comparison observations "nearby" in the propensity score distribution. This is the common support or overlap condition and ensures that persons with the same X values have a positive probability of being both participants and non-participants (Heckman et al., 1999). The common support thus represents the area where there are enough of both, control and treatment observations. The common support region allows effective comparisons of outcomes between the treated and control groups.

Assuming the CIA holds and that there is overlap between both groups, the average treatment effect can then be estimated. One ideally wants to estimate $\Delta = Y_t^1 - Y_t^0$, which is the difference of the outcome variable of interest at time t between two groups, denoted by the superscripts 1 and 0. However, the econometrician is unable to estimate Δ in this way because a household cannot simultaneously be in treatment and control group. The econometrician is thus forced to measure the average treatment effect (*ATE*) given the observable data:

$$ATE = E(Y_t^1 | T = 1) - E(Y_t^0 | T = 0) \qquad (19)$$

When data are generated through a properly implemented random experimental design, the expectations of the treatment and comparison groups are equal because the groups are composed of randomly allocated members (households), ensuring that the distribution of observable and unobservable characteristics of the groups are equivalent in a statistical sense. With a randomized design, the selection bias equals zero, which establishes that the estimate of the ATE provides an unbiased estimate of its impact.

Randomized experiments are not always possible (such as in the case of estimation of the impacts of HPAI on livelihoods) or plausibly implemented, so that absence of selection bias is a credible assumption. Hence, econometricians are often forced to estimate the average treatment effect on the treated households (*ATT*), given a vector household characteristic, *X.:*

$$ATT = E(\Delta | X, T = 1) - E(Y_t^1 - Y_t^0 | X, T = 1) = E(Y_t^1 | X, T = 1) - E(Y_t^0 | X, T = 0) \qquad (20)$$

To estimate potential effects of HPAI incidence, propensity scores are used to match households with similar observable characteristics, varying only the treatment, which in this case is having poultry (and therefore being susceptible to HPAI). Households are matched to each other conditional on a set of observable household characteristics. A probit model is estimated using a vector of household characteristics to obtain predictions of household propensity scores. Heckman, *et al*. (1998) observe that the PSM have lower bias when X includes variables that affect both program participation and the outcome. The household-level characteristics (e.g., household demographics, assets, regional characteristics such as location, poverty status, number of income sources, etc.) included in the model are therefore those that have a high probability of influencing participation in poultry production, as well as outcome variables including livelihoods indicators such as livestock income and wealth. According to this method of matching, the two groups, which include treatment group of households representing the result of the HPAI demand or supply shocks, and a control group representing the status quo (if no HPAI shocks occurred), should differ only in terms of their poultry ownership characteristics.

In this study we simulated six counterfactual scenarios to estimate possible impact of HPAI on livelihood indicators (income and asset wealth) for poultry producing households. These scenarios consider the livelihoods impacts of both demand (Scenario 4) and supply shocks (all other scenarios), as well as the impact of the supply shocks on poultry keepers of different scales. Specifically, small-scale poultry producers are allocated into two groups across study countries, with 'smaller' small-scale producers representing those poultry producers with one bird to 25^{th} percentile number of birds, and more intensive 'larger' small-scale producers having more than 25^{th} percentile number of birds but less than 500 birds, where 500 is the cut off point for small-scale household level poultry keeping in the study countries (see Alemu et al., 2008; Aning et al., 2008; Omiti &Okuthe, 2008; Obi et al., 2008). Across scenarios, scenario 2 considers the impact of HPAI on "smaller" small-scale producers, whereas scenarios 3 and 6 consider the impact of HPAI on "larger" small-scale producers. Moreover, integration of our impact assessment with the diseases risk maps developed by Stevens et al (2009) enables us to measure the livelihoods impacts in different risk areas (scenarios 5 and 6).

Scenario 1 assumes a country-wide shock where all poultry producing households in the study country experience total loss (i.e., 100% loss) of their poultry flock due to HPAI. In this scenario outcomes of households with poultry are compared to those without poultry.*Scenario 2* investigates the impact of HPAI on 'smaller' small-scale poultry producers. The assumption is that only those households with 'smaller' small-scale flocks are affected by HPAI and they lose all (100%) of their flocks. *Scenario 3* assumes only 'larger' small-scale producers are adversely affected by HPAI, and they lose some of their birds and are left with a flock size similar to that of the 'smaller' small-scale producers.

Scenario 4 assesses the impact of a price shock caused by HPAI. We assume this shock would be countrywide. We looked at the impact of a price shock on the livelihoods outcomes of those chicken producers who sell poultry. Of those households who sell chicken we compared households who get higher prices (above median chicken price in each country) to those who get lower (below median) prices.

Scenarios 5 and *6* use the disease spread map developed by (Stevens *et al*, 2009), which shows the likelihood for spread of HPAI in each study country, assuming that the disease has been introduced for those countries where there is no HPAI. In *scenario 5* households located in the areas with high HPAI spread risk are assumed to be affected by HPAI and loose 100% of the birds. Similar to the first scenario, poultry producing households are compared to those with no poultry; however in this scenario only those households in the high risk areas are matched. Finally, in *scenario 6* we use the disease spread risk map to identify medium risk areas in each study country (Stevens *et al*, 2009). Similar to scenario 3, this scenario assumes only 'larger' small-scale producers are adversely affected by HPAI and they lose some of their birds and are left with a flock size similar to that of the 'smaller' small-scale producers, however in this scenario only those households in the medium risk areas are matched. These scenarios are summarized in Table 1.

Table 1: Description of HPAI scenarios for poultry-keeping at the household level

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5***	**Scenario 6***
Description of simulated impact	100% loss of poultry flock	100% loss of small-scale poultry flocks	75-85% loss in large-scale poultry flock	50% reduction in poultry price	100 % loss of poultry flock in high-risk areas	75-85% loss in large-scale poultry flock in medium-risk areas
Treatment group	All households without poultry	All households without poultry	Small-scale poultry keepers (1 to x birds)	Poultry keepers who sold at low prices	All households without poultry	Small-scale poultry keepers (1 to x birds)
Control group	All households with poultry	Small-scale poultry keepers (1 to x** birds)	Large-scale poultry keepers (x-500 birds)	Poultry keepers who sold at high prices	All households with poultry	Large-scale poultry keepers (x to 500 birds)

*For scenarios 5 and 6, country level disease spread maps (Stevens et al. 2009) were used to allocate locations (districts, provinces or zones) into high HPAI spread risk and medium HPAI spread risk areas; ** x represents the 25th percentile number of birds in each study country

4. Data sources and descriptive statistics

4.1. Data sources

In this study we rely on the latest nationally representative data from each study country. There are two advantages to using nationally representative data to study the role of poultry in the households' livelihoods and the impact of HPAI thereon. First, having nationally representative data enables us to investigate the regional or location-related variations, such as urban vs. rural areas or high HPAI risk vs. low HPAI risk regions, which targeted case studies may not allow for. Second, the data sets used in this study are from studies whose aim is to monitor the changes in the welfare (poverty) levels in the study countries through time. Consequently, these studies have collected detailed data on the households' various sources of income and livelihoods strategies, as well as on the type and quantity of assets owned by the households. Therefore these data sets allows us to investigate in detail the role of poultry (both as a source of income and as an asset) in the entirety of the households' income and asset portfolios.

Regarding the sources of data used in this study, for the West African countries we used the Living Standards Measurement Study (LSMS) survey data. For Nigeria we use Nigerian Living Standard Survey, 2004-5 (NLSS, 2004-5), which was collected by the National Bureau of Statistics, the World Bank and National Planning Commission. For Ghana we use the Ghana Living Standards Survey 2005-6 (GLSS, 2005-6), which was conducted by Ghana Statistical

Service with financial assistance from the World Bank. The data used for Kenya comes from the Kenya Integrated Household Budget Survey, 2005-6 (KIHBS, 2005-6), implemented by Kenya National Bureau of Statistics and the Human Resources Social Services Department of the then Ministry of Finance and Planning. Finally for Ethiopia we used the data from the Household Income and Consumption (HICE) survey conducted in 2004-5, collected by the Ethiopian Central Statistical Authority. Each one of these studies collected data on the number of poultry kept by the sampled households in the study year, and in the case of Kenya, Nigeria and Ghana, on the number of poultry sold and the price sold at. For Ethiopia, we relied on monthly producer price data collected in 2004/05 by the Central Statistical Authority to derive the value of poultry owned by the households.

4.2. Descriptive Statistics

According to the nationally representative data, 30% of all Nigerian households engage in small-scale poultry production, whereas this figure is 35% for Ghanaian households, and 42% and 43% for Ethiopian and Kenyan households, respectively. Table 2 presents these statistics also for urban and rural households.

Table 2. Percentage of poultry producing households, average flock size and percentage of poultry income in total income

	All households	Rural households	Urban households
ETHIOPIA			
% households that keep poultry	41.94	41.40	43.42
Avg. flock size of poultry keepers	4.82	4.81	4.83
KENYA			
% households that keep poultry	43	54	15
Avg. flock size of poultry keepers	1.99	2.02	1.41
% poultry income in total income for poultry keepers	2.1	2.1	1.7
GHANA			
% households that keep poultry	34.6	51.43	11.03
Avg. flock size of poultry keepers	13.74	13.77	13.54
% poultry income in total income for poultry keepers	4.16	4.40	2.00
NIGERIA			
% households that keep poultry	29.70	37.20	6.33
Avg. flock size of poultry keepers	16.94	16.92	17.26
% poultry income in total income for poultry keepers	5.61	5.63	5.08

According to these results, Nigeria supports the smallest proportion of urban poultry producing households, whereas in Ethiopia poultry production is almost as popular in urban areas as it is in rural areas. Across the study countries, the largest flocks are kept by Nigerian poultry producing households with almost 17 birds, and the smallest flocks are kept by Kenyan poultry producing households with two birds.

In this study, total annual household income includes salaries from industry employment (agriculture, mining, manufacturing, services, and so on); income from livestock and crop sales; and remittances, rent income, and other reported income. On average, poultry (live bird) and egg sales contribute 4.1 percent to the poultry-producing household's total annual household income in Ghana, whereas this figure is as low as 2.1% in Kenya and as high as 5.61% in Nigeria. In Ethiopia HICE data did not include information on the amount of live birds and eggs sold by the households, therefore we could not calculate the share of income from poultry in total income for this country.

For poultry producing households, the share of poultry income in total income and the number of birds kept across income quintiles are reported in Table 3. The figures for Nigeria, Kenya and Ghana reveal that the flock size increases and the share of income obtained from poultry decreases with income quintiles. That is poorer households rely on poultry more to provide some of their livelihoods and they have fewer birds compared to their wealthier counterparts. In Ethiopia, however, the average flock size is similar across income quintiles, and since we do not have information on the amount of live birds and eggs sold by the households we cannot calculate the share of income from poultry for this country.

Table 3. Average flock size and percentage of total poultry income in total income across income quintiles, poultry keeping households

	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
ETHIOPIA					
Average flock size	4.98	4.67	4.64	4.66	4.85
KENYA					
Average flock size	2.29	6.53	5.43	5.88	7.35
% income from poultry	5.55	4.13	0.45	0.20	0.09
GHANA					
Average flock size	9.78	11.96	12.95	14.21	19.68
% income from poultry	14.49	2.19	0.99	0.58	0.51
NIGERIA					
Average flock size	15.62	16.37	16.86	17.32	18.61
% income from poultry	15.96	4.19	2.11	1.08	0.25

5. Results

5.1. Role of poultry in household livelihoods

5.1.1. Determinants of participation in poultry production

Household, farm level and regional factors that affect households' decision regarding whether or not to partake in poultry production are investigated with a probit model, as explained in section 3.1 above. Probit models were estimated for each country and the results of these models are reported in Table A1 in the appendix. For details of the country level models please see the country reports (Ayele et al., 2010; Mensa-Bonsu et al., 2010; Ndirangu et al., 2010 and

Okpukpara et al., 2010). The probit models were used to predict each household's likelihood of being a poultry keeper. Those households with above 50% probability of being a poultry keeper were considered as predicted poultry-keepers and those with below 50% probability of being a poultry keeper were coined as predicted non-keepers of poultry. Household, farm and location characteristics of predicted poultry-keeper households were compared to those of predicted non-keepers. The significant results of these comparisons are reported in Table 4.

Table 4. Household predicted to be poultry keepers have…

Household, farm and regional characteristics	ETHIOPIA	KENYA	GHANA	NIGERIA
Larger households	✓	✓	✓	✓
More adult women in the household	✓	✓	✓	✓
More children in the household	✓	✓	✓	✓
Older household heads	NS	✓	✓	✓
Less educated household heads	✓	✓	✓	✓
More income sources	✓	✓	✓	✓
Other livestock production (small)	✓	✓	✓	✓
Other livestock production (large)	✓	✓	✓	✓
Crop production	✓	✓	✓	✓
Less off farm employment/income	✓	✓	✓	✓
Lower income per capita	✓	✓	✓	✓
Income below extreme poverty line	NS	✓	NS	x
Higher livestock wealth	✓	✓	NS	✓
Higher overall wealth (house, land, livestock)	NA	✓	NS	✓
Rural location	✓	✓	✓	✓

When compared to the predicted non-keepers of poultry, households who are predicted to be poultry keepers have significantly larger households. This is as expected since as the number of people in a household increases, both the household food and nutrition security needs and the household labour availability increases. In all countries, households with higher proportion of adult women and children are more likely to be engaged in poultry keeping. This result is also as expected since previous studies have shown that women and children tend to be involved in the rearing and selling of poultry (e.g. Aklilu et al., 2007; Sonaiya, 2007). Children, especially in rural areas, often own one or two birds to meet their costs of school materials (Hailemariam et al, 2006), whereas women are widely recognised to be the most important stakeholders in village level poultry keeping in Africa, owning over 70% of all household level poultry (Alder, 1996; Gueye, 1998; Gueye, 2000).

In all of the countries households with less educated heads and in majority of the study countries households with older heads are significantly more likely to keep poultry. The former result can be explained by the fact that in the study countries household-level poultry production is a low-input, low output activity, which does not require high levels of skill and education (see e.g., Alemu et al., 2008; Aning et al., 2008; Omiti &Okuthe, 2008; Obi et al., 2008). Similarly, households with older heads are more likely to keep poultry, since it is a low labour-intensive livelihoods activity which older households may be able to undertake.

Regarding livelihoods portfolios of households, it is found that in all countries households with more diversified livelihoods portfolios, i.e., those with a higher number of income sources, and those engaged in other agricultural livelihoods strategies (e.g., other livestock and/or crop production) are more likely to be poultry keepers. Since poultry contributes very small proportion of household income, as discussed in section 4.2., this result is as expected. Moreover various previous studies have found that poultry production is often complementary with crop production, since farm manure and crop land area are inputs to poultry production as providing feed and area for scavenging/roaming. In fact previous studies found that households who own higher numbers of plots and/or larger areas are more likely to keep livestock (see, e.g., Wadsworth, 1991; Klein et al., 1997). Moreover, households who own other livestock are also more likely to be engaged in poultry production since several studies have found that poultry is the first step in the livestock ownership ladder (e.g., Gueye 2000; Aklilu et al., 2008). Therefore overall, households who are predicted to be poultry keepers have diversified agricultural livelihoods strategies, and consequently their livelihoods outcomes are more likely to be the resilient towards shocks and stresses which may be cause by HPAI outbreaks and scares (Ellis, 2000; Iiyama, 2006).

In all of the study countries predicted poultry keepers are found to have a lower number of household members with non-agricultural income and/or lower off farm incomes. These results reveal that it is the more agricultural, subsistence or semi-subsistence oriented farm households who are engaged in poultry keeping. This result is also supported by the finding that households located in rural areas are more likely to be poultry keepers, as suggested by the descriptive statistics presented in Table 2 above, since off-farm income opportunities are fewer in rural areas. Moreover, households who have lower income per capita are more likely to be poultry keepers. This result is also expected since household level poultry keeping is often coined as a livelihoods activity favoured by the poor due to its high return rate compared to its low input investment requirements. The impact of having income below the poverty line on household's likelihood of being poultry keeper is however mixed across countries. In Kenya households who are below the poverty line are more likely to keep poultry whereas the opposite holds for Nigeria. For Kenya this result is consistent with the finding that that larger households with higher adult female ratios are more likely to have incomes below the poverty line and to engage in poultry keeping (KPIA, 2009). In Nigeria this finding can be explained by the fact that in this country to partake in poultry production some minimum level of financial investment is needed, which may not be affordable by the households whose incomes are below the poverty line. Finally in terms of wealth, we see that in all countries except Ghana households who have higher livestock wealth (market value of livestock owned) are more likely to keep poultry. This result is as expected since households who have other livestock are more likely to own poultry as poultry is the first step in livestock ladder as mentioned above. Kenyan and Nigerian households who are wealthier in terms of other assets (e.g., house and land) are also more likely to keep poultry, possibly due to the complementarities between poultry production and crop production.

To identify the regional variations within the study countries, we used the probit model to calculate the percentage of households who are predicted to keep poultry in rural and urban areas, and in the different regions/districts of the countries, as see that in the low, medium and high risk areas as identified by Stevens et al (2009). According to the probit model for Nigeria, 23% of all Nigerian households; 32% of rural Nigerian households and only 4% of urban Nigerian households are predicted to be poultry keepers. Across geo-political zones, a greater majority of households located in the Northern Zones (45% in North West, 36% in North East and 28% in North Central) are predicted to rear poultry. Among the southern Zones, South East is the zone with the highest proportion of predicted poultry keepers with about 29% of households in this region predicted to keep poultry. Only 2.4% of all households located in the South West zone are predicted to be poultry keepers. According to the HPAI risk spread map developed by Stevens et al (2009) the high HPAI risk areas in Nigeria mainly covers the South East Zone, and the medium HPAI risk areas include North Central, East and West.

According to the Ghana probit model, one fifth of all Ghanaian households and 37% of rural Ghanaian households are predicted to be poultry keepers whereas only 4.9 % urban households are predicted to keep poultry. Greater proportions of households located in Upper East (80%), Upper West (56%), Northern (55%) and Volta (42%) regions are predicted to be small scale poultry keepers compared to households located in other regions. These four regions also fall under the high HPAI risk areas identified by Stevens et al (2009). Medium HPAI risk areas in Ghana include Central, Western, Eastern, Ashanti, and Brong Ahafo regions.

In Kenya the probit model predicted 34% of all Kenyan households are predicted to be poultry keepers. Across provinces 25% of all households in the Eastern province are predicted to keep poultry, followed by Nyanza (22%), Western (19%) and Rift Valley (17%) provinces. In terms of their urban vs. rural location 53% of all rural households are predicted to keep poultry whereas this figure is as low as 3% for urban households. According to the Stevens et al (2009) disease spread risk map for Kenya, the high HPAI risk areas includes districts in Western and Nyanza provinces, whereas medium HPAI risk areas include districts in Coast and Rift Valley provinces.

Finally, the probit model for Ethiopia predicted 60% of all Ethiopian households to keep poultry. This figure is 66% in rural areas and 53% in urban areas, revealing that poultry keeping is a popular livelihoods activity in both urban and rural locations. Across regions, Tigray supports the highest proportion of households predicted to keep poultry with 87%. Tigray is followed by Afar (86%), Benishangul Gumuz (71%) and Somale (65%). According to the Stevens et al (2009) disease spread risk map for Ethiopia, the high HPAI risk areas includes Benishangul, Northern parts of Oramiya, Addis Ababa, Tigray, and Amahara, whereas the medium HPAI risk areas include southern parts of Oromiya, SNNPR, Somale, and Dire Dawa. Therefore, overall, in each one of the study countries, greater proportions of households located in riskier areas are likely to be poultry keepers.

5.1.2. Determinants of poultry flock size

Zero Inflated Negative Binomial (ZINB) model was used to describe the determinants of the size of flock managed by the households. In the logit component of the ZINB model (inflate panel) only the significant explanatory variables in the estimated Probit models were used to determine the households' likelihood of being a 'certain zero' i.e., not keeping poultry. In the second component of the ZINB model for those households who are not certain zeros, the household, farm and regional level factors that affect the size of the poultry flock they manage were estimated. The second part of the ZINB model for the study countries are presented in the Appendix Table A2. For details of the country level models please see the country reports (Ayele et al., 2010; Mensa-Bonsu et al., 2010; Ndirangu et al., 2010 and Okpukpara et al., 2010).

The probabilistic ZINB model is used to predict the flock sizes for each household that is predicted to participate in poultry keeping (i.e., not certain zero). According to these predictions, an average predicted poultry-keeper household in Nigeria is predicted to keep five birds in one year, whereas this figure is six birds in Kenya, as low as two birds in Ethiopia and as high as 11 birds in Ghana. In each country households predicted to keep mean and above number of birds (i.e., 'larger' small-scale producers) are compared to those households who are predicted to keep below predicted mean number of birds. The results of these comparisons are summarized in Table 5 below.

Table 5. Households predicted to keep larger flocks have ….

Household, farm and regional characteristics	ETHIOPIA	KENYA	GHANA	NIGERIA
Larger households	✓	✓	✓	✓
More adult women in the household	X	✓	✓	✓
More children in the household	✓	✓	✓	✓
Older household heads	✓	✓	✓	✓
Less educated household heads	✓	x	x	✓
More income sources	✓	✓	✓	✓
Other livestock production (small)	✓	✓	✓	✓
Other livestock production (large)	✓	✓	NS	✓
Crop production	✓	✓	✓	✓
Less off farm employment/income	✓	✓	✓	✓
More income per capita	NS	NS	x	x
Income below extreme poverty line	NS	NS	✓	✓
Higher livestock wealth	✓	✓	✓	✓
Higher overall wealth (houses, land, livestock)	NA	✓	✓	✓
Rural location	✓	✓	✓	✓

Households which are larger, and which have older heads and more or higher proportion of women and children are more likely to keep 'larger' small-scale flocks. The impact of education on the size of the flock managed is mixed across countries. In Ethiopia and Nigeria more educated households are less likely to keep larger flocks, whereas the opposite is true for Kenya and Ghana. This result may be explained by the fact that 'larger' small-scale flocks in

Ghana and Kenya keep larger flocks, and hence would require higher levels of investment (in housing, veterinary inputs, marketing etc) which could be undertaken by more educated household heads.

As with participation in poultry production, households who have more diversified livelihoods portfolios (i.e., those with higher number of income sources, those who are engaged in crop and other livestock production) are more likely to keep ‘larger’ small scale flocks. Again, similarly to participation in poultry production, those households located in rural areas and hence those with fewer off farm employment opportunities are more likely to keep larger flocks. The evidence is however mixed with regards to the income level and the poverty status of the ’larger’ small-scale producers. In Ghana and Nigeria those households who have lower income per capita and those who are below the extreme poverty line are more likely to be ’larger’ small-scale poultry producers. Revealing that the livelihoods outcomes of these producers may be affected by HPAI related demand and supply shocks.

Finally, in terms of wealth variables, households with higher livestock wealth (across all four countries) and other wealth (e.g., land, across all countries except Ethiopia where data on wealth were not available) are more likely to keep ’larger’ flocks. Therefore, even though poorer (in terms of disposable income) may be more likely to keep ’larger’ flocks in Ghana and Nigeria, these households are wealthier in terms of asset value, and hence, combined with their diversified livelihoods portfolios, they may be able to hedge against the HPAI shocks and stresses.

In terms of their location, we see that in Nigeria, households who are predicted to keep the largest flocks are located in the North West and North Central zones, with about eight birds, followed by South East and North East with about seven birds. As mentioned above South East is a high HPAI risk area, whereas the three Northern zones are medium HPAI risk areas. In Ghana households in the Western region keep the largest flocks with about 13 birds. Western is followed by Volta and Ashanti regions (with 12 birds) and Central and Eastern regions (with an average of 11 birds). Among those Volta is a high HPAI risk area, whereas the others are medium HPAI risk areas, as defined by Stevens et al (2009).

In East Africa, Kenyan households who are predicted to manage the largest average flocks are located in the Nyanza, Coast and Western provinces (with around seven birds each). As mentioned above, among these provinces Nyanza and Western are located in high HPAI risk areas, whereas Coast is located in medium HPAI risk areas. Finally in Ethiopia, where the predicted flock sizes are the smallest across the four study countries, households in Tigray, Somale and Afar provinces are predicted to keep the largest flocks (about three birds) in that country. Of these three regions Tigray is classified as a high HPAI risk area, whereas Somale is identified as a medium HPAI risk area by the Stevens et al (2009) risk map. Overall, in both East and West African countries, we see that households located in those areas that have higher risks of HPAI spread, keep larger than national average size of household level, small-scale flocks.

5.2. Impact of HPAI on poultry producing households’ livelihoods

In this study we investigate the livelihoods impacts of HPAI demand and supply shocks on two livelihoods indicators, namely livestock income (i.e., income from the sales of livestock) and livestock wealth (i.e., market value of livestock owned), data on which are readily available from the nationally representative household surveys. Two aspects of these outcomes should be mentioned. First, livestock income, as a livelihoods outcome, is expected to have impact on various other livelihoods outcomes, such as current food and nutrition security, and gender equality, as explained above. Similarly, livestock wealth is expected to have impacts on current livelihoods outcomes, such as nutrition from currently owned livestock (e.g., eggs or meat) as well as future livelihoods outcomes, such as future livestock income and hence future food and nutrition security. Therefore even though we are focusing on two livelihoods outcomes (income and wealth) due to the availability of nationally representative data on these, we can argue that these two outcomes are indicators of other important outcomes (current and future).

Second, it should be noted that HPAI may have indirect impacts (positive or negative) on these livelihoods outcomes through other pathways. For example livelihoods of households who produce complementary inputs to poultry production (e.g., maize) or those whose members may be employed in sectors that are directly linked to poultry (e.g., commercial poultry farms or restaurants) may also be negatively affected. Similarly, households who produce other livestock in addition to or instead of poultry (e.g., small ruminants or cattle) may experience positive impacts on their livelihoods if the value of these increase as a result of substitution effects. In this paper we abstract ourselves from these other possible pathways through which HPAI may impact livelihoods and focus only on poultry production.

As explained in section 3.3., to estimate the impact of HPAI on poultry-producing households' livelihoods outcomes, six artificial counterfactual scenarios were created and investigated. The analysis involved matching households in treatment and control groups for the scenarios described in Table 1, by using the propensity score matching (PSM) method.

In each scenario, livelihood outcomes of a treatment group of households, representing the result of HPAI demand or supply shocks, were compared to a control group, representing the status quo (no HPAI shocks). The groups were matched according to various household-level characteristics (household demographics, assets, and regional characteristics such as location, poverty status, and number of income sources) expected to affect a household's propensity to be in the treatment situation as well as their outcomes (livestock income and livestock wealth). According to this method, the two groups should differ only in poultry ownership characteristics. The results of this analysis are presented in Table 6.

Across scenarios, only the HPAI shocks presented in scenarios 3 and 6 had significant affects on the livelihoods outcomes of poultry producers in all of the study countries. According to scenario 3, if an average poultry producing household that manages a 'larger' small-scale flock lost 75 to 85% (depending on the country) of its flock due to HPAI, its total livestock wealth would decrease by half in Ethiopia, by almost a third in Kenya and almost by a quarter in Ghana. This scenario also affects livestock income, reducing it by almost a third in Kenya and almost by half in Nigeria

Table 6: Estimated impact of HPAI on the livelihood outcomes of household-level poultry producers in the study countries

	ETHIOPIA	KENYA		GHANA		NIGERIA	
Scenarios:	Livestock wealth	Livestock Income (total income)	Livestock Wealth (total wealth)	Livestock Income (total income)	Livestock Wealth (total wealth)	Livestock Income (total income)	Livestock Wealth (total wealth)
1 – All Country: Lose all poultry	-	-	-	17% (0.8%)	-	-	-
2 – All Country: Lose all small flocks	-	-	-	-	-	-	-
3 – All Country: Large flocks become small flocks	51%	28%(7%)	31%(6%)	-	23%(12%)	42% (7.4%)	-
4 – Poultry Sellers: High price falls to low price	-	-	-	-	-	-	-
5 – High HPAI Risk: Lose all poultry	-	67%(8%)-	46%(4%)	22% (1.6%)	-	-	-
6 – Medium HPAI Risk: Large flocks become small flocks	31%	-	41%(9%)	30% (0.5%)	31%(16%)	39%(8%)	21%(15%)

According to scenario 6, in medium HPAI risk areas if an average poultry producing household that manages a ’larger’ small-scale flock lost majority of its birds to HPAI, its total livestock wealth would decrease by a third in Ethiopia and Ghana, by almost a half in Kenya and by one fifth in Nigeria. The impact of this scenario on livestock incomes of ‘larger’ small-scale producers is significant in Ghana and Nigeria, where these producers may be losing around a third of their livestock income as a result of this shock.

The HPAI shock presented in Scenario 5 had significant impacts on only Kenyan and Ghanaian poultry producing households’ livelihoods outcomes. In Kenya if all poultry producing households in the high HPAI risk areas lost all of their flocks, on average they would lose as much two thirds of their annual income from livestock, and almost half of their total livestock wealth. In Ghana, this scenario amounts to reduction in livestock incomes by one fifth.

6. Conclusions and policy implications

In this study we have investigated the role of poultry in the livelihoods of small-scale household-level poultry producers in four selected Sub-Saharan African (SSA) countries and the livelihoods impacts of supply and price shocks that may be caused by the demand and supply shocks caused by HPAI outbreaks and scares. The selected SSA countries included Nigeria, Ghana, Kenya and Ethiopia which have provided a spectrum of countries in terms of HPAI status and the role of poultry in household income.

Our results revealed that across the four SSA countries the profiles of households who are predicted to be poultry keepers and those who are predicted to keep “larger” small-scale flocks are quite similar. In each one of the study countries, households that are more likely to keep poultry and to keep “larger” flocks have older and less educated household heads, are larger with more children and with more adult women. These results support previous studies which found that in the study countries, as well as in other SSA countries, small-scale poultry production is a livelihoods activity mainly undertaken by women and children of the household to meet their immediate cash expenditure needs (e.g., school expenses, unexpected health expenditures etc). These findings have implications in terms of the importance of poultry in intra-household gender equality, and for development outcomes where incomes managed by women have been found to result in improved outcomes for family, particularly for children (for example in terms of health, nutrition, and education). In addition, the elimination of poultry from children's diets as a result of HPAI outbreaks could have nutritional repercussions that ultimately could have impacts on their future livelihoods (Iannotti et al. 2008). Detailed household-level livelihoods research on these topics is warranted.

In terms of asset ownership, households who are predicted to be poultry keepers and those who are predicted to keep "larger" flocks have higher average values of livestock wealth and other assets (e.g., land). Moreover, these households have more diversified livelihoods strategies, as evident from their significantly higher number of income sources and participation in other livelihoods activities (e.g., crop production, other livestock production). Therefore, for predicted poultry-keeper households and for those households who are likely to keep "larger" flocks, poultry is one of several livelihood strategies/assets geared toward building their resilience against shocks. Therefore these households are likely to be resilient against HPAI-related demand and supply shocks.

To estimate the impact of HPAI on poultry-producing households' livelihoods indicators (income and asset wealth), especially those pertaining to livestock, six artificial counterfactual scenarios were created and investigated. The scenario were: (1) 100% loss of poultry flock; (2) 100% loss of small-scale poultry flocks; (3) 75-85% loss (depending on the country model) in large-scale poultry flock; (4) 50% reduction in poultry price; (5) 100 % loss of poultry flock in high-risk areas; (6) 75-85% loss (depending on the country model) in large-scale poultry flock in medium-risk areas.

The results of the impact assessment reveals that across the all four study countries, households with "larger" small-scale flocks, are more vulnerable to HPAI in terms of livestock income and/or wealth (asset value) loss. Depending on the scenario, country and the riskiness of the area in which the households are located, the magnitude of loss in total asset value (4%-16%) and total annual household income (0.5%-8%), reveal that the "larger" small-scale poultry producing households stand to lose most from HPAI related shocks. Furthermore, according to the diseases spread risk maps developed by Stevens et al (2009) for these countries, a great majority of these "larger" small-scale producers are located in the medium to high HPAI spread risk areas. Therefore these households seem to be most vulnerable to HPAI related shocks.

Given the magnitude of loss in assets and income for the poultry producing households with "larger" small-scale flocks and the important role of poultry in the sustainability of future livelihoods (through gender equality and nutrition), targeted intervention measures should be in place to encourage the adoption of HPAI mitigation measures, and households with "larger" small-scale flocks should be given special focus when designing preventive, training and compensation programs. Further diversification of farming activities, savings and investment in other non-farm activities should also be stressed to help minimize adverse effects of HPAI shock on the livelihoods of the households. Policy measures to support capacity building and create incentives for investment in poultry production, especially in biosecurity, are of fundamental importance for the strengthening of the small-scale poultry sector against shocks such as HPAI. Since households with higher proportion of children are found to be more likely to keep poultry and to manage larger flocks in both urban and rural areas, particularly school children could be an entry point for efforts to improve biosecurity levels in the country. Similarly, given the role of women in poultry rearing, they should also be encouraged to be actively involved in training programs and in dissemination of information regarding biosecurity technologies.

Finally there are implications of our results for other shocks to livelihoods, whether through livestock diseases or general. As it is evident from the results of this study, the poor often have diversified livelihoods strategies and therefore an idiosyncratic shock that affects only one of the many livelihoods strategies (e.g., poultry production) and/or one of the several livelihoods assets (e.g., poultry flock) they may own, should not have as significant of an effect on the overall livelihoods outcomes as covariant shocks (such as draughts) which may affect several of the livelihoods strategies and assets at once. The framework and data presented in this paper would be suitable for the analysis of idiosyncratic shocks (such as livestock or crop diseases) however more dynamic frameworks and analyses are required to study the impact of covariant shocks on household level livelihoods.

7. References

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8. Appendix

Table A1: Summary of Probit models in study countries (Determinants of participation in poultry production)[1]

Household, farm and regional characteristics	ETHIOPIA (N=15374)	KENYA (N=12640)	GHANA (N=5531)	NIGERIA (N=6443)
Constant	-0.400*** (0.105)	-4.240*** (0.261)	-2.178*** (0.214)	-2.386*** (0.230)
Age of head of household	-0.009** (0.004)			
Age of head of household squared	0.000 (0.000)			
Skill of head of household (age*years of education)		0.018*** (0.004)	0.003 (0.008)	-0.003 (0.007)
Skill of head of household squared		-0.001* (0.001)	0.000 (0.000)	0.000 (0.000)
Education years of head of household		0.046*** (0.013)	-0.082*** (0.019)	-0.012 (0.028)
Education years of head of household squared		-0.001* (0.001)	0.003*** (0.001)	0.000 (0.001)
Household size		0.026** (0.010)	0.054*** (0.016)	0.018 (0.013)
Proportion of females in household with age above 15 years old	-0.010 (0.013)	0.136 (0.117)	0.054 (0.108)	0.157 (0.116)
Proportion of household members with age below 18 years old	0.024*** (0.009)	0.413*** (0.105)	-0.021 (0.140)	0.479*** (0.123)
Number of income sources	0.018 (0.024)	0.655*** (0.020)	0.507*** (0.029)	0.035 (0.032)
Household engages in non-farm income-generating activities, dummy		-0.764*** (0.047)	-0.914*** (0.072)	
Household has access to formal credit				0.551* (0.306)
Number of plots	0.133*** (0.006)			
Household has pack animals (donkey, horse and/or mule), dummy	0.248*** (0.025)			0.096 (0.143)
Household raises sheep, dummy	0.404*** (0.023)			0.645*** (0.102)
Household raises goat, dummy				1.955*** (0.067)
Household raises pig, dummy				0.976*** (0.271)
Area of residence (rural=1, urban=0), dummy	-0.273 (0.177)		0.236** (0.092)	0.871*** (0.077)
Household is core poor, dummy	-0.066 (0.058)	-0.376*** (0.107)	-0.633*** (0.207)	-0.376*** (0.091)
Interaction variable of area of residence and household core poor	0.384** (0.178)	0.334** (0.116)		
Density of poultry population in district		0.534*** (0.118)		

[1] regional dummies were excluded from the table due to space concerns (please see Ayele et al. (2010), Mensa-Bonsu et al (2010), Ndirangu et al (2010) and Okpukpara et al (2010) for detailed tables of these models; significance level *** p<0.01, ** p<0.05, * p<0.1

Table A2: Summary of count models (ZINB) in study countries (Determinants of poultry flock size)[1]

Household, farm and regional characteristics	ETHIOPIA (N=18507)	KENYA (N=12627)	GHANA (N=1683)	NIGERIA (N=6443)
Constant	1.303*** (0.113)	2.025*** (0.084)	2.509*** (0.207)	2.290*** (0.210)
Age of head of household[1]	-0.003 (0.004)			
Skill of head of household (age*years of education) [2]		0.017*** (0.004)	0.000 (0.001)	0.020*** (0.010)
Education years of head of household[1]	0.002 (0.003)	0.044*** (0.004)	-0.006 (0.020)	-0.010 (0.020)
Size of household		0.027*** (0.007)	0.064*** (0.013)	0.040*** (0.010)
Proportion of females in household with age above 15 years old	-0.026* (0.014)	-0.410*** (0.099)	-0.285* (0.149)	0.330* (0.170)
Proportion of household members with age below 18 years old		-0.117 (0.086)	-0.469*** (0.143)	0.280** (0.130)
Proportion of household members with age between 6 an 14 years old	-0.020** (0.010)			
Number of income sources	-0.006 (0.025)	0.065*** (0.014)	0.007 (0.026)	-0.030 (0.020)
Household engages in non-farm income-generating activities, dummy			0.003 (0.073)	
Household has access to formal credit				0.550** (0.250)
Household has pack animals (donkey, horse and/or mule), dummy	0.126*** (0.025)			
Household raises cattle, dummy	0.062** (0.026)			0.150** (0.070)
Household raises sheep, dummy	-0.011 (0.023)			0.030 (0.050)
Household raises goat, dummy				-0.050 (0.050)
Household raises pig, dummy				-0.030 (0.110)
Area of residence (rural=1, urban=0), dummy	0.018 (0.027)		0.047 (0.072)	-0.100 (0.090)
Household is core poor (total expenditure less than national average for food expenditure=1, otherwise=0), dummy	0.030 (0.057)	-0.459*** (0.122)	0.082 (0.266)	-0.090 (0.070)
Interaction variable of area of residence and household core poor		0.233*** (0.126)		
Density of poultry population in district		0.077 (0.075)		
Zero observations	9877	7629	300	4652
Non-zero observations	8630	4998	1683	1791
Vuong test, z-value	29.66***	34.24***	7.11***	32.90***

[1] regional dummies were excluded from the table due to space concerns (please see Ayele et al. (2010), Mensa-Bonsu et al (2010), Ndirangu et al (2010) and Okpukpara et al (2010) for detailed tables of these models). [2] – squared variables of age, education, and skill were also estimated but yielded not-statistically significant estimates and were omitted. Standard errors presented in brackets; significance level *** p<0.01, ** p<0.05, * p<0.1